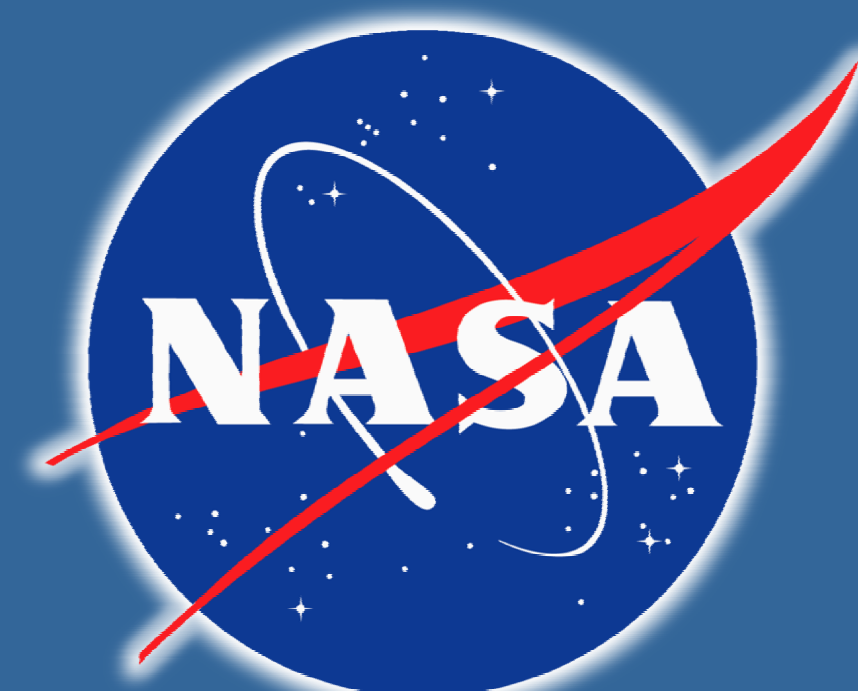# Prognostics for Electronics
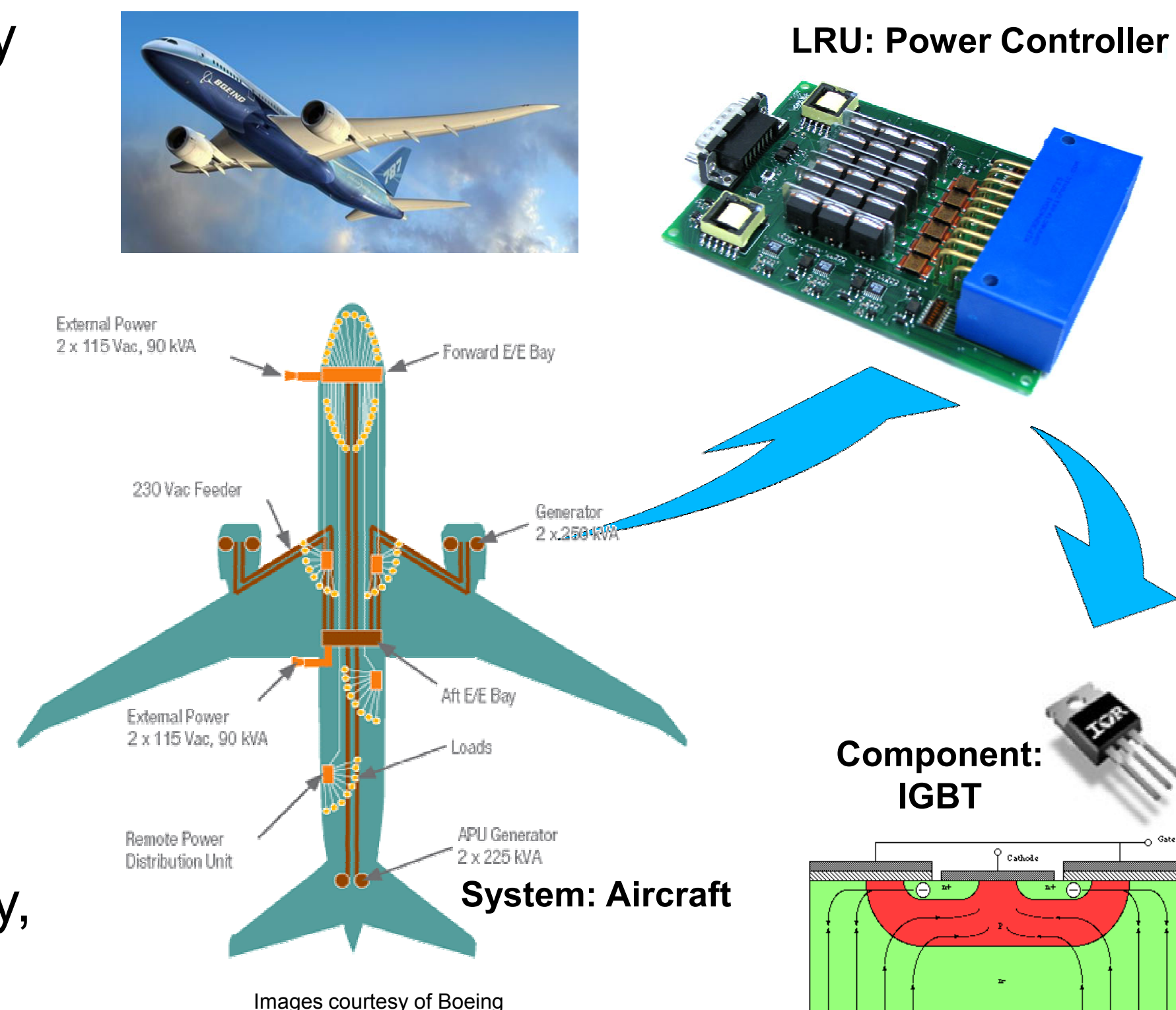
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### Prognostics Center of Excellence, NASA ARC

Overview

Motivation

- Electronic components have an increasingly critical role in on-board autonomous functions for vehicle controls, communications, navigation, and radar systems. Future aircraft systems will rely more heavily on electric and electronic components

- To obtain an understanding of the behavior of deteriorated components, as well as the capability to anticipate failures and predict the remaining life of embedded electronics

- Investment in prognostics technologies can enable risk mitigation and increase reliability, while lowering cost for redundant systems

LRU: Power Controller

External Power
2 x 115 Vac, 90 kVA

Forward E/E Bay

230 Vac Feeder

Generator
2 x 250 kVA

External Power
2 x 115 Vac, 90 kVA

Aft E/E Bay

Loads

Remote Power
Distribution Unit

APU Generator
2 x 225 kVA

System: Aircraft

Images courtesy of Boeing
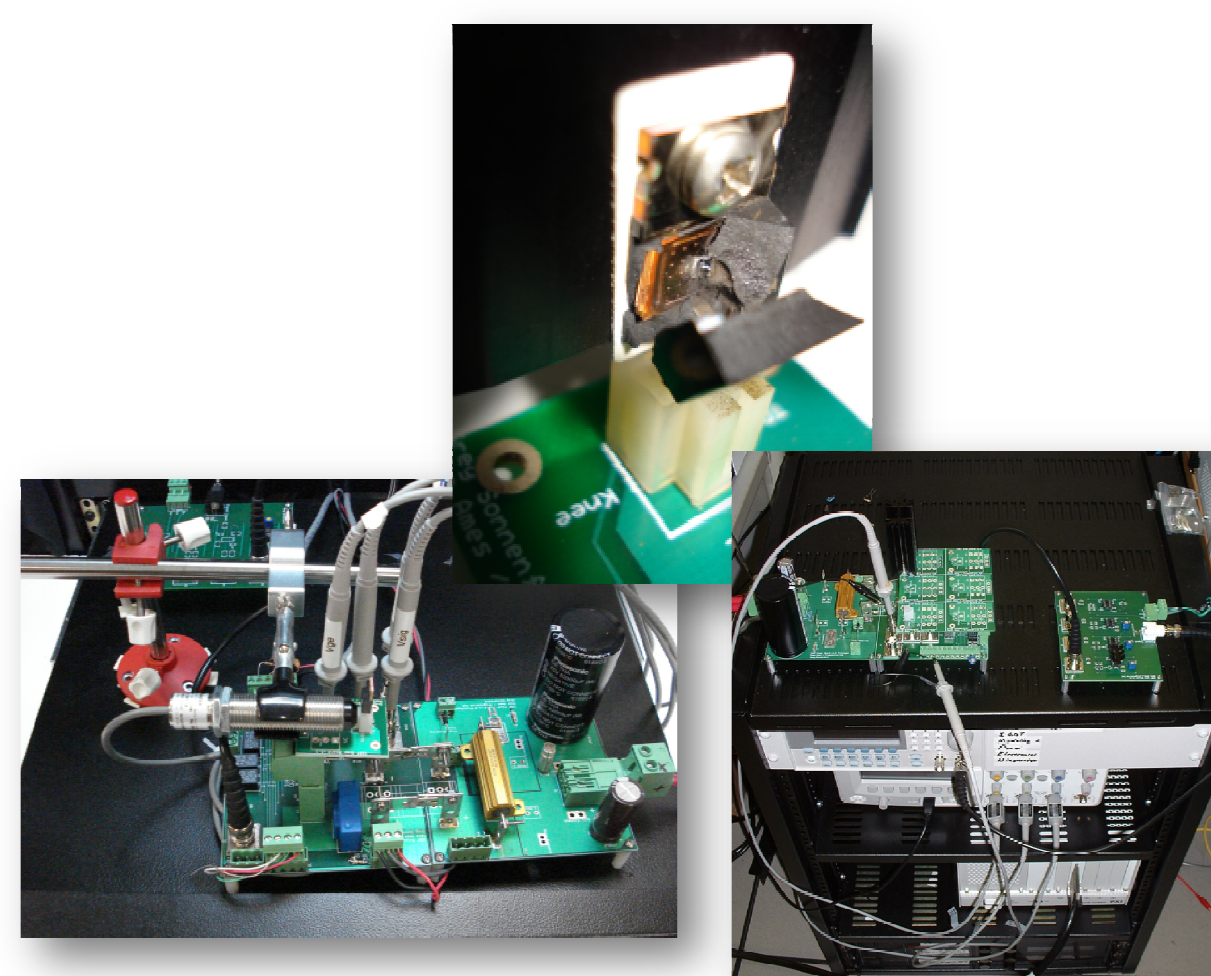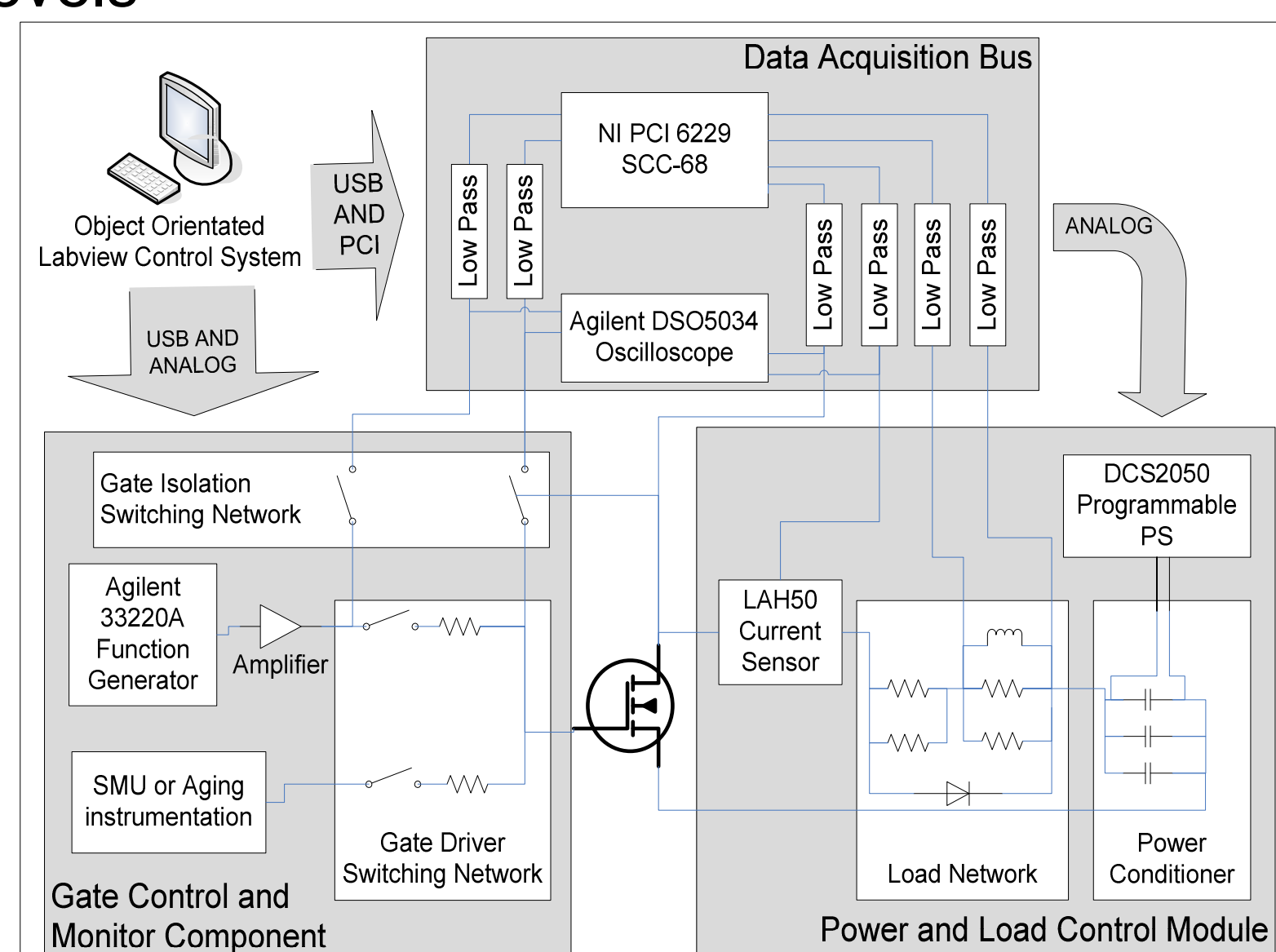
Component: IGBT

Objectives

- Identify new and unexplored fault modes and failure mechanisms
- Identify precursors of failures in faulty components
- Discover physics-of-failure models of the degradation process
- Predict the remaining useful life of components and embedded electronics based on physics-of-failure models and identification of precursors of failures
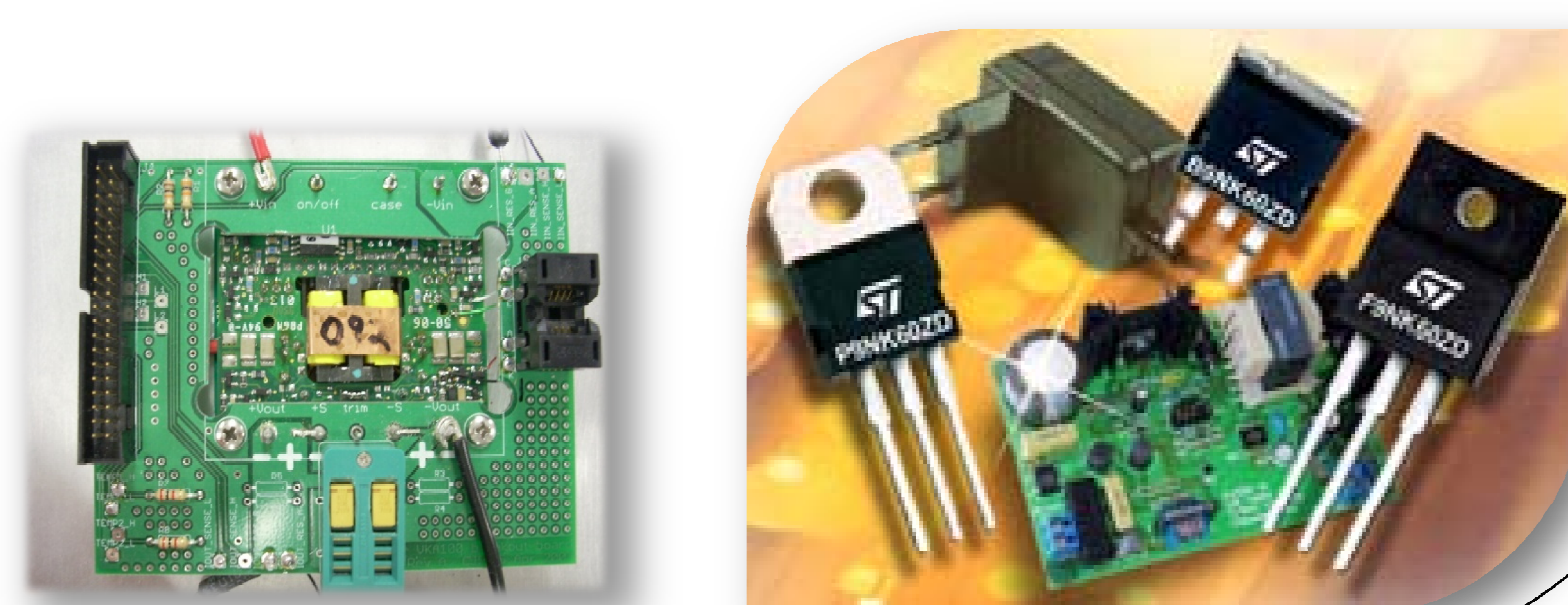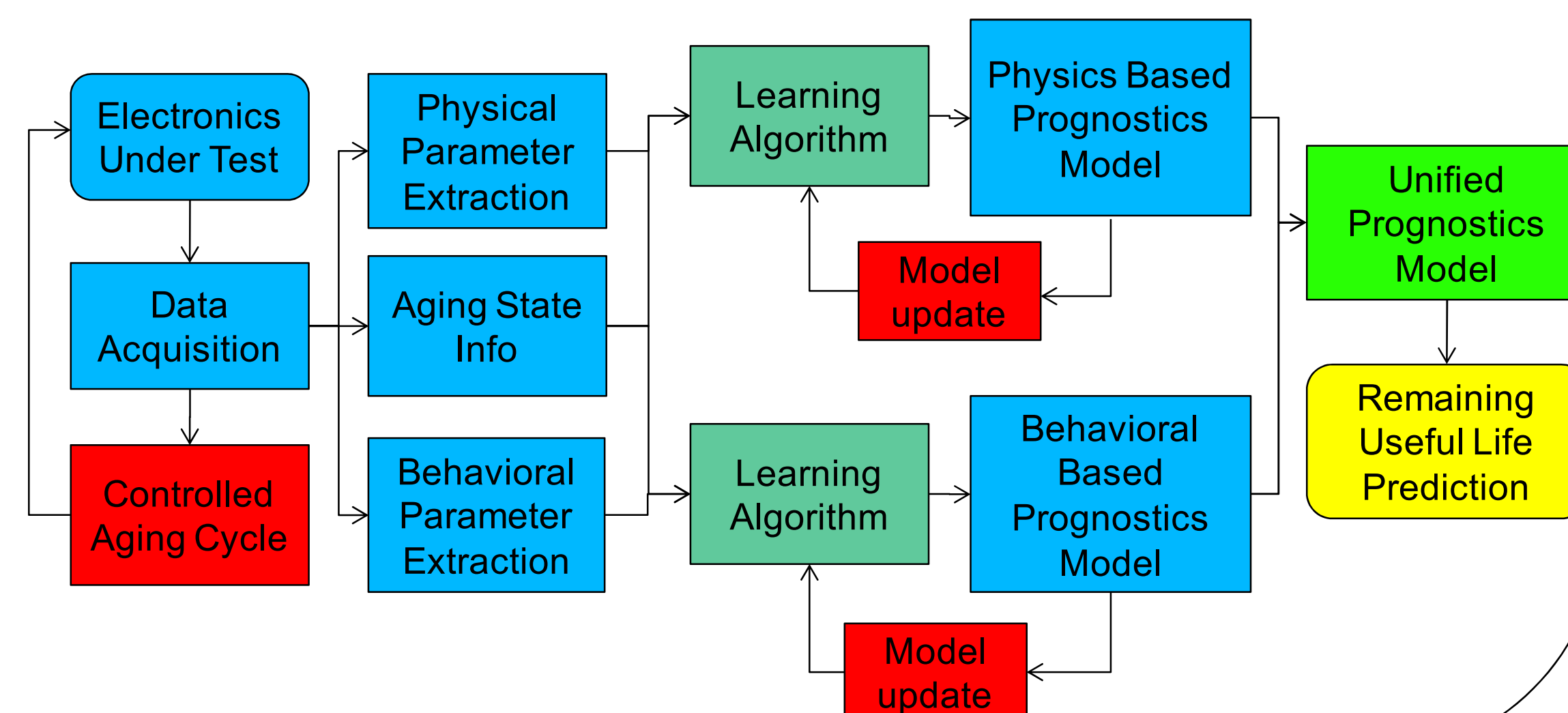
Methodology

Aging and Characterization System

- Enables aging and characterization of gate-controlled power transistors
- Supports thermal cycling, dielectric over-voltage, acute/chronic thermal stress, and current overstress
- In-situ state monitoring, including measurements of the steady-state and transient voltages and currents, and thermal transients at varying gate and drain voltage levels

Data Acquisition Bus

Object Orientated Labview Control System

USB AND PCI

USB AND ANALOG

NI PCI 6229 SCC-68

Low Pass

Agilent DSO5034 Oscilloscope

ANALOG

Gate Isolation Switching Network

Agilent 33220A Function Generator

Amplifier

SMU or Aging instrumentation

Gate Driver Switching Network

LAH50 Current Sensor

DCS2050 Programmable PS

Load Network

Power Conditioner

Gate Control and Monitor Component

Power and Load Control Module

Remaining Useful Life

- Provide health state indicators in a continuous manner through integration of model and feature-based algorithms
- Update physics-based damage accumulation and aging models based on monitored features
- Estimate health based on anticipated usage profile and execution of the damage propagation model
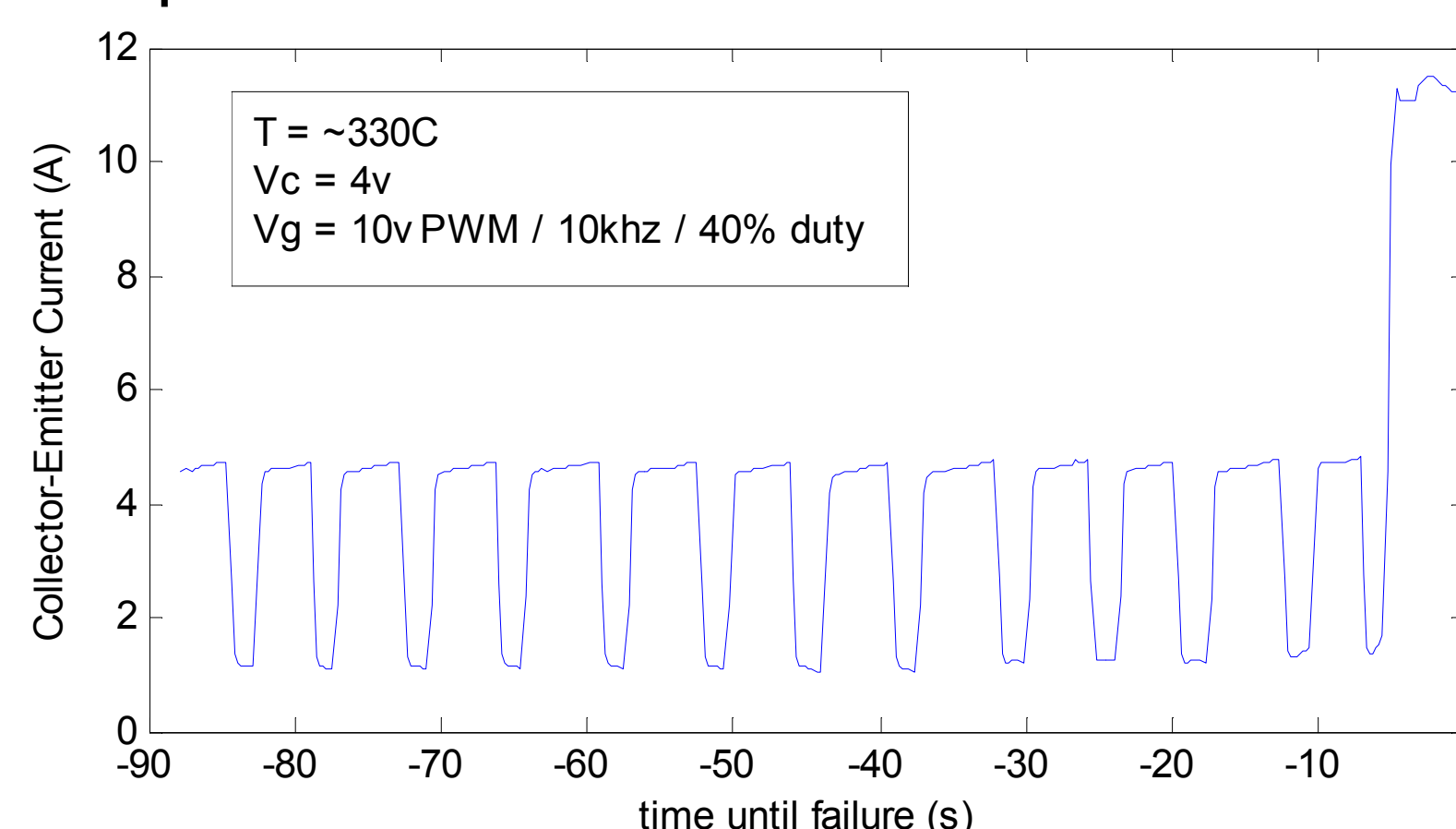
Electronics Under Test → Physical Parameter Extraction → Learning Algorithm → Physics Based Prognostics Model

Data Acquisition → Aging State Info

Model update

Controlled Aging Cycle → Behavioral Parameter Extraction → Learning Algorithm → Behavioral Based Prognostics Model

Model update

Unified Prognostics Model → Remaining Useful Life Prediction
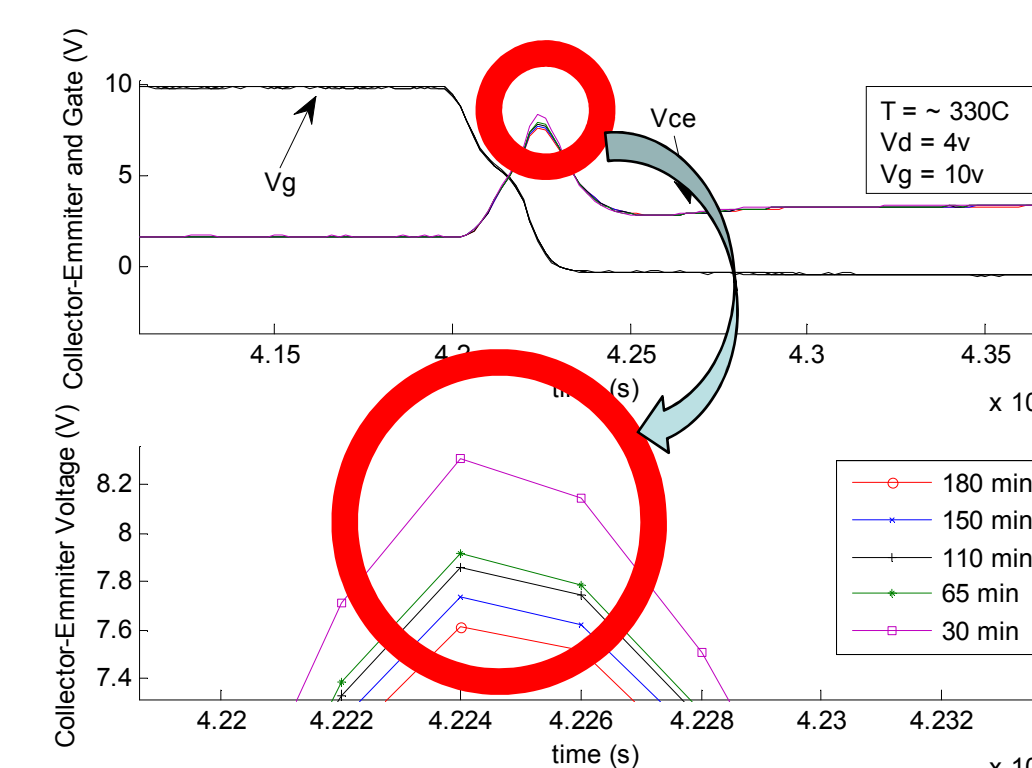
Results

IGBT Experiments

- A preliminary thermal overstress aging test was conducted on IGBTs
- International Rectifier IRG4BC30KD with 600V/15A rating in a T0220 package
- The temperature was measured from the IGBT package without external heat
- The experiment was stopped after thermal runaway or latch-up failure
- A hysteresis temperature controller was used to control the aging process switching the gate voltage
- Aging experiment settings:
  - Serial resistive load of 0.2 Ohms
  - Gate driven by a PWM signal at 10V, 10KHz and 40% duty cycle
  - Power supply at 4V on load circuit
  - Temperature thresholds: Low=329°C, High=330°C, and Runaway= 340°C

Failures

- The average collector-emitter current was monitor during the during the experiment in order to detect a latch-up condition
- Latch-up failure occurred at ~90 minutes of aging. As a result, gate control was lost. In addition, the device was found to be functional after returning to room temperature

T = ~330C
Vc = 4v
Vg = 10v PWM / 10khz / 40% duty

Collector-Emitter Current (A)

time until failure (s)

Precursor of Failure

T = ~330C
Vd = 4v
Vg = 10v

Vce

Vg

180 min
150 min
110 min
65 min
30 min

The collector-emitter voltage turn-OFF transient showed a significant decrease in its peak value with increase in temperature and aging time

Switching Transient peak(V)

Degradation time (s)

temperature (C)